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Construction Cost and Erosion Control Effectiveness of Filter Windrows on Fill Slopes

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Michael J. Cook
John G. King¹

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ABSTRACT

Sediment barriers of slash were designed and constructed on the fill slopes of newly constructed roads. These barriers called filter windrows were located in the vicinity of stream crossings in an attempt to prevent eroded fill material from entering the stream. The contractor was able to construct windrows at a rate of 170 ft/h (52 m/h), using a track-mounted Caterpillar 235 hydraulic pull shovel (a large backhoe). The cost of this fill slope treatment was \$59 per 100 feet (30 m) of windrowed slope. A conservative estimate of the sediment trapping efficiency of the windrows is 75 to 85 percent, based on measurements of fill slope erosion on windrowed versus non windrowed slopes. The results indicate that the construction of filter windrows on fill slopes is a relatively inexpensive and a very effective treatment for preventing eroded material from entering adjacent streams. Filter windrows can be constructed simultaneously with road construction, providing immediate protection of the water resources.

KEYWORDS: road erosion, sedimentation, erosion control

Surface erosion from roads, especially fill slopes, is greatest during the first year following construction. Megahan's (1972) 6-year study of sediment production from a logging road in the Idaho Batholith revealed that 83.8 percent of the total surface erosion occurred during the first year following construction, with an additional 9.4 percent occurring during the second year. Another study of fill slope erosion in the Horse Creek drainage of

north-central Idaho (USDA 1981) reported that 56 percent of the erosion over a 2-year period occurred in the first 2.5 months after construction. Subsequent reduction of the surface erosion rate is due to vegetation establishment and armoring of the slopes.

Slope stabilization measures are often delayed until the autumn following the construction season. Thus, the newly exposed slopes are subject to erosion during convective summer storms. Treatments of seed, fertilizer, and mulch are not completely effective until after seed germination and growth the following spring. Other techniques that incorporate the use of netting or mats are expensive.

The objective of this study was to demonstrate a sediment control technique that utilizes natural materials, provides immediate protection to live streams, requires no additional disturbance width, is esthetically acceptable, and is inexpensive. The technique is to construct sediment barriers, called filter windrows, on the fill slopes adjacent to streams. In this study, filter windrows were constructed with logging slash, long known as a deterrent to sediment movement and readily available from the right-of-way clearing operation. Fill slope erosion was monitored on windrowed and nonwindrowed slopes to quantify the technique's effectiveness.

SITE DESCRIPTION

This project was undertaken in the Horse Creek Administrative-Research Study Area, located in the Nezperce National Forest approximately 35 miles (56 km) east of Grangeville, Idaho (fig. 1). Elevations in the 7,700-acre (3 116-ha) watershed range from 4,110 feet (1 253 m) to 6,025 feet (1 836 m). Grand fir (*Abies grandis*) is the major tree species. Other species include Douglas-fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), Englemann spruce (*Picea englemannii*), subalpine fir (*Abies lasiocarpa*), and Pacific yew (*Taxus brevifolia*).

¹Michael J. Cook is a forest engineer with the Nezperce National Forest, Grangeville, Idaho; John G. King is a hydrologist located at Intermountain Station's Forestry Sciences Laboratory, Moscow, Idaho.

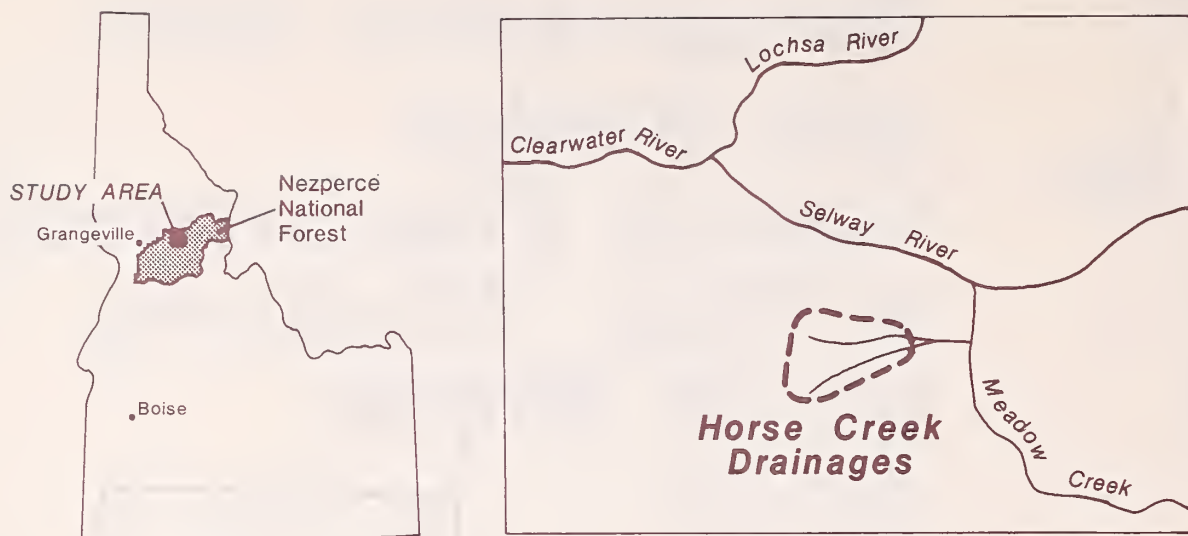


Figure 1.—Location of the Horse Creek Administrative-Research Area.

The area's climate is influenced by modified maritime air masses from the Pacific Ocean. Average annual precipitation is 48 inches (122 cm), 60 to 70 percent of which occurs as snow. The wettest month is January and the driest month is July. Summer convective storms occur from late June through mid-September. The maximum monthly average temperature of 59° F (15° C) occurs in August and the minimum of 17° F (-8° C) occurs in January. Winter temperatures are generally moderate and winter melt is common.

Four major soil types occur in the study area. In order of the percentage of the area they occupy, they are: loessial silt loams, 10 to 30 inches thick (25 to 76 cm); loams to sandy loams, 12 to 30 inches thick (30 to 76 cm); loessial silt loams, 2 to 4 feet thick (61 to 122 cm), overlaying hard mica schist and quartzitic gneisses; and loessial silt loams, 6 to 18 inches thick (15 to 46 cm), overlaying micaeous loams (USDA 1976). The road was constructed on an SM type (silty sand), often grading to a GM type (silty gravels) or a GW type (gravel-sand mixture) at a depth of about 2 feet (60 cm), based on the Unified Soil Classification System (Wotring 1981).

The climate and topography are typical of much of northern Idaho, eastern Washington, and western Montana. Steep slopes and erodible soils present a challenge to land managers concerned with protecting streams, spawning areas, and the total forest ecosystem.

CONSTRUCTION PHASE

Planning

Field work consisted of staking areas for windrow construction, determining the proximity of suitable slash, and selecting stockpile sites. Generally, the entire length of fill slope that could contribute directly to streams was designated for windrow construction. The average length of windrows on the project was 250 feet (76 m), with a range of 70 to 450 feet (21 to 137 m).

Project specifications and a drawing were prepared for inclusion in the road construction contract (appendix). The type of windrow selected was one that would require no additional clearing, would provide a low profile conforming to the fill slope, and would utilize readily available materials.

Construction

Construction was accomplished in two phases. First, during clearing and pioneering at designated sites, suitable material was stockpiled at the upper edge of the staked clearing limits. This did not require any additional time. Coordination between the contractor and engineer insured that stockpile areas would not interfere with planned work and would be conveniently located for later use. Location of stockpiles, either above or below the clearing limits, can easily be modified to accommodate many different clearing operations and contractor requirements.

Second, windrows were constructed by moving a cull log from the stockpile, placing it in position at the toe of the fill, and anchoring it into place against stumps, rocks, or trees with the pull shovel (fig. 2). Stockpiled slash was then placed on the fill slope above the cull log (fig. 3) (see appendix for dimensions). The windrow was compacted by tamping the slash with the shovel. This produced a relatively dense windrow embedded in the top 6 inches (15 cm) of the fill surface. It is important that the slash be embedded to prevent flow of material through or under the slash.

All work in the second phase was accomplished from the road subgrade as fill construction progressed, using a track-mounted Caterpillar 235 hydraulic pull shovel (a large backhoe) with a 360 degree swing. Equipment was the same as that used during the clearing and stockpiling operation. Manual laborers were not required.

All fill slopes were constructed with a 1½:1 slope. The road travelway was stabilized with an 8-inch (20-cm) lift of gravel. In the fall following construction, the fill slopes were seeded, hydromulched, and fertilized.



Figure 2.—Placement of the cull log at the toe of the fill slope.



Figure 3.—Filter windrow 2 years after construction.

Construction Monitoring

Construction was monitored during the clearing and pioneering operation and during filter windrow construction. A total of 1,190 feet (363 m) of windrows were constructed at five stream crossings. All windrows were constructed without interruption.

The total equipment time for construction of all filter windrows was 7.0 hours. Included in equipment time were the equipment move-in and move-out time, the

equipment production time, and the average equipment travel speed. Equipment was walked from other work within the project at an average speed of 5 mi/h (8 km/h). Move-in and move-out times were approximately 0.5 hours each. The pull shovel was able to construct 200 lineal feet (61 m) of windrow per hour once at the site. This production time includes movement of cull logs and slash from stockpiles, placement on the slopes, and compaction. Average distance from stockpile to windrow was 350 feet (107 m) and between windrow locations it was 0.2 mile (0.3 km). No equipment breakdowns were encountered. Times will vary with the equipment used and the site. The production rate for windrow construction on this project, considering travel time to the sites, was 1,190 feet (363 m) in 7.0 hours or 170 ft/h (52 m/h).

WINDROW PERFORMANCE

The effectiveness of the filter windrows in preventing eroded material from leaving the fill slopes was measured in two different ways. The first method involved placement of 4-foot-long (1.22-m) troughs, with a capacity of 1 ft³ (0.03 m³), immediately below the windrows to collect eroded material transported through or over the windrows. In the second method, the volumes of all rills and gullies in the fill slopes above the windrows and transport distance below the windrows, if any, were measured.

Collection Troughs

Fifteen troughs were installed along the 1,190 feet (363 m) of windrowed fill slopes in 1978, within 1 week following windrow construction. Five troughs were placed below fills with vertical heights of less than 10 feet (3 m), or class 1 slopes. Ten troughs were placed below fills ranging in height from 10 to 20 feet (3 to 6 m), or class 2 slopes. The material in the troughs was removed and volumetrically measured, with an estimated measurement error of ± 5 percent, following all major rain storms, once each late fall, and once each spring from July 1978 through August 1981. The volumes of material in the troughs were averaged for the two height categories of fill slopes and are expressed as ft³/100 ft of road (m³/1 000 m).

The total amount of eroded material transported through the windrows during the 3 years after road construction was 0.325 ft³/100 ft (0.302 m³/1 000 m) for class 1 slopes and 0.650 ft³/100 ft (0.603 m³/1 000 m) for class 2 slopes (fig. 4). Erosion of fill slopes not protected with filter windrows for this same period was 35.85 ft³/100 ft (33.29 m³/1 000 m) for class 1 slopes and 64.30 ft³/100 ft (59.70 m³/1 000 m) for class 2 slopes (fig. 4). Thus, approximately 99 percent of the eroded fill material was deposited within the windrow. Over a 3-year period the windrows reduced the amount of sediment leaving the fill slopes by 163 ft³ (4.6 m³) for class 1 slopes and 465 ft³ (13.2 m³) for class 2 slopes.

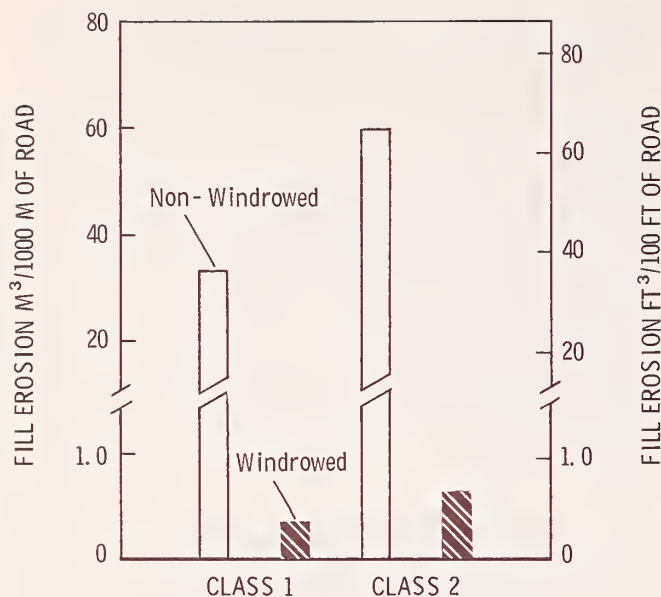


Figure 4.—Fill erosion volumes for windrowed and nonwindrowed slopes by vertical height class during the 3 years following construction.

Gully Surveys

Surveys of the rills and gullies formed in the fill slopes above the filter windrows were made each spring and fall for 3 years following road construction. Measurements of average top width, bottom width, and length of the rills were used to determine volumes, with an estimated measurement error of ± 15 percent. In addition, the void volumes of material displaced by slumping above the windrows were measured. If material was transported either through or over the windrow, the downslope travel distance was measured.

The total amount of eroded material transported to all the windrows as rill and gully erosion was 187.0 ft³ (5.3 m³) for the 3-year period. An additional 115.5 ft³ (3.27 m³) of material was displaced by slumping, but the fraction of this slumped material reaching the windrows was not determined.

Figure 5 shows the cumulative rill and gully erosion above the filter windrows. The rate of erosion decreased rapidly with time. After 2 years the slopes were well-vegetated and the majority of the rills and gullies were stabilized. A survey in the summer of 1981 indicated that only 3 of the 36 gullies were still active and that they were beginning to stabilize.

In the 3 years since windrow construction there have been only seven instances when eroded fill slope material was transported past the windrows. Material reached the streams in only three of these instances. Windrow failures were usually associated with slumping, which occurred in late spring when the fill slopes were saturated with snowmelt water. In several cases, the windrows were still partially covered with snow and the slumped material moved over the windrow. In other cases, the subsequent rill erosion in slumped material was transported through the windrows.

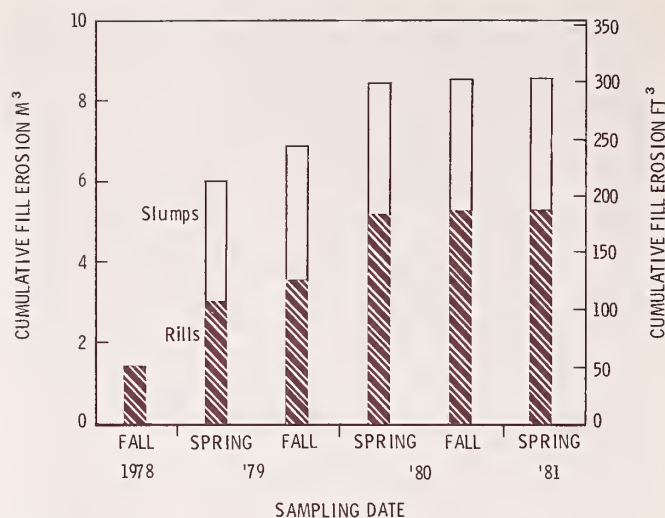


Figure 5.—Cumulative rill and slump erosion of the fills above the filter windrows for the 3 years following construction.

The windrows were effective in reducing downslope transport distance even when they were breached because only a small fraction of the sediment passed through the windrow. Average transport distance below the windrows was 3.8 feet (1.2 m) while average transport distance below unprotected fill slopes was 24.2 feet (7.4 m) if slumping had not occurred and 41.4 feet (12.6 m) below slumped areas of fill.

An accurate determination of the trapping efficiency of the windrows using the rill volume data is not possible because there was no measure of volumes being transported through the windrows. A conservative estimate of trapping efficiency is 75 to 85 percent if the assumption is made that 50 percent of volume was transported through the windrow at each breach.

SUMMARY

The contractor was able to construct 170 feet (52 m) of filter windrow per hour at a cost of \$59 per 100 feet (30 m) of windrow. Over the 3 years since construction the windrows have been very effective (75 to 85 percent) in preventing material from leaving fill slopes. The cost of preventing 628 ft³ (17.8 m³) of sediment from leaving the slopes was \$700 (\$39.33/m³). Total costs will vary with the abundance of suitable materials, travel distances between locations, and care taken in locating and flagging slash stockpiles.

The use of filter windrows on fill slopes at stream crossings is an inexpensive and effective method for minimizing delivery of eroded fill material to streams. With increasing concern over maintaining desirable habitats for trout and anadromous fish, the authors recommend this practice as one means of preventing sediment from entering streams at road crossings. Windrows can be constructed shortly after road pioneering to provide immediate protection to the streams.

Other management considerations relative to the use of filter windrows include fire hazard, the possibility of insect infestation, wildlife movement patterns, and

esthetics. As constructed in Horse Creek, big game can easily cross the windrows. If windrows are constructed continuously along the length of the road, perhaps not only for reducing erosion but also for disposing of part of the slash produced during clearing, then these other considerations become more important.

The vertical heights of the windrowed fill slopes ranged from 5 to 20 feet (1.5 to 6.1 m). The effectiveness of windrows on fill slopes with higher erosion rates—for example, on steeper or higher fills, more erosive soils, or sites where revegetation may be slower—may be less than reported for this study.

Eventual decay and weakening of windrows may allow downslope movement of stored sediment in subsequent years if stabilization by revegetation has not occurred. In Horse Creek, virtually all of the fills that were seeded and mulched have excellent vegetative cover. The authors believe that subsequent gradual decay of the slash in the windrows will not cause a significant release of stored sediment for downslope movement. These windrowed slopes will be observed for the next few years to evaluate their long-term performance.

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APPENDIX

SPECIAL PROJECT SPECIFICATIONS

SECTION 201A - FILTER WINDROW

Description

201A.01 - It is the intent of this specification to provide for the construction of a windrow of logging slash that will act as a sediment trap or filter to reduce erosion effects from newly constructed fill slopes.

Materials

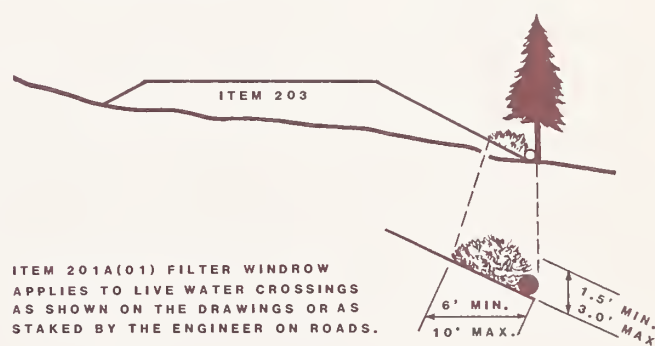
201A.02 - Suitable slash shall be conserved from Item 201(01) Clearing and Grubbing, and stockpiled at approved sites. Slash to be conserved shall consist of tops, limbs, and brush not to exceed 6 inches in diameter, and 12 feet in length. Stumps and root wads shall not be included.

Construction Requirements

201A.03 - Logs of not less than 18-inch diameter shall be placed on the fill slope immediately above and parallel to the toe for the windrow to catch against. Reasonably sound cull logs may be used if available. They shall be firmly anchored against undisturbed stumps, rocks, or trees, or as otherwise directed by the Contracting Officer's Representative (COR).

All material in the windrow shall be placed to form a neat, compact, and uniform pile. Windrows shall be placed so that they do not interfere with the functioning of drainage structures or block stream channels.

Windrows shall be constructed only in locations staked by the COR, on the fill slope immediately above the toe as shown on the drawings.



FILTER WINDROW DIMENSIONS

Methods of Measurement

201A.04 - The amount to be paid for shall be the number of linear feet of windrow, as measured along the toe of the fill, completed and accepted.

Basis of Payment

201A.05 - The accepted quantities of windrow, determined as provided above, will be paid for at the contract unit price, which price and payment will be considered full compensation for the work prescribed in this item. Payment will be made under:

Pay item	Pay unit
201A(01) Filter Windrow.....	Linear foot

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